IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re: Application of:	) Title: Organic Electroluminescence Generating Devices
Michele Muccini, *et al*	)
	) Group Art Unit: 2891
Serial No: 10/550,860	)
US National Phase of PCT/EP2004/003111	) Examiner: Such, Matthew W.
International Filing Date: March 24, 2004	)

DECLARATION UNDER 37 C.F.R. §1.131

Sir:

The undersigned, Michele Muccini, declares and states as follows:

1. I am one of the inventors of the above-captioned patent application directed to organic electroluminescence generating devices. I have direct knowledge of the events leading to the preparation and filing the above-captioned patent application and the priority patent application.
2. I am Head of the Research Unit "Optoelectronics and Photonics" of Consiglio Nazionale delle Ricerche Institute for Nanostructured Materials (CNR-ISMN) in Bologna, Italy. My Curriculum Vitae is attached as Exhibit A.
3. I have read and understand the subject matter of the above-captioned application. I have also read the Office Action mailed on April 2, 2010, including the following references cited therein: Hepp et al, *Light-Emitting Field-Effect Transistor Based on a Tetracene Thin Film*, Physical Review Letters, Vol. 91, No. 15, pp. 157406-1 through 157406-4

(from hereon, Hepp); US Patent No. 6,828,583 (from hereon, Heeger); US Patent No. 5,596,208 (from hereon, Dodabalapur); WO 03071608 (from hereon, Hiroshi); Rogers et al *Low-Voltage 0.1 micron Organic Transistors and Complementary Inverter Circuits Fabricated With a Low-Cost Form of Near-Field Photolithography*, Appl. Phys. Lett., Vol. 75, No. 7 (16 August 1999); pp. 1010-1012 (from hereon, Rogers); and US Patent Application Publication No. 2003/0122120 (from hereon Brazis, Jr.)

4. I understand that the Office Action has rejected claims 1-3, 5, 6, 8, 12-16, 21, 22 and 24-28 as anticipated by Hepp; claims 4, 19 and 20 as being obvious over Hepp in view of Heeger; claims 1-6, 8, 15, 16, 19-22 and 24-28 as being obvious over Heeger in view of Dodabalapur and Hiroshi; claim 12 as being obvious over Heeger in view of Dodabalapur, Hiroshi and Rogers; and claims 13 and 14 as being obvious over Heeger in view of Dodabalapur, Hiroshi and Brazis, Jr.
5. I hereby attest that I, together with my co-inventors, invented the subject matter of all pending claims before October 10, 2003 (the publication date of Hepp), before March 12, 2003 (the earliest effective date of Heeger), and before August 28, 2003 (the earliest effective date of Hiroshi).
6. I also hereby attest that the invention was reduced to practice at least as early as February 3, 2003.
7. The following describes how, when and where the invention was made.
8. Starting from December 2001, several research groups were working on a common research project which was the basis of the invention and the resulting patent application. These research groups included: Technische Universität Darmstadt (Darmstadt, Germany); Interuniversitair Micro-Electronica Centrum VZW (Leuven, Belgium);

Université Louis Pasteur (Strasbourg, France); Centre National De La Recherche Scientifique (Strasbourg, France); International Business Machines Research GmbH (Rüschlikon, Switzerland), and the Consiglio Nazionale delle Ricerche (headquartered in Rome, Italy).

9. On February 3, 2003 a meeting of the Steering Committee of the project was held in Bologna, Italy. Participants at the meeting were: Aline Hepp, Michele Muccini, Raymond Ziessel, Paul Heremans, Heinz von Seggern, Sigfried Karg.

10. At this meeting, the research group based in Technische Universität Darmstadt presented to the others a scientific report (under confidentiality agreement). The report was authored by Aline Hepp, Holger Heil, Roland Schmechel and Heinz von Seggern. The content of this report is substantially the same as that of Hepp.

11. A copy of the report signed by the participants at the meeting is attached as Exhibit B to this Declaration.

12. The scientific report discloses the invention which formed the basis of the instant patent application.

13. Specifically, the scientific report describes in detail the invention, and in particular, the features of claim 1.

14. For example, the scientific report states and demonstrates the following:

    - a channel of a single thin layer of a single polycrystalline small molecule material whereby said single polycrystalline small molecule material has a crystal grain size. See, Exhibit B, Abstract (page 1); Fig. 1 (page 2); and Fig. 8 (page 5);
    - the channel is able to carry electrons and holes. See, Exhibit B, Fig. 8 (page 5);
    - an electron electrode (Drain in Figs. 1 and 8) which is in contact with the channel and positioned on top of a first side of the channel layer (Fig. 8) or within the channel layer (Fig. 1), where the electron electrode is being able to

inject electrons in the channel layer. See, Exhibit B, Fig. 1 (page 2) and Fig. 8 (page 5);

- a hole electrode (Source in Figs. 1 and 8) which is spaced apart from the electron electrode, where the hole electrode is in contact with the channel and positioned on top of the first side of the channel layer (Fig. 8) or within the channel layer (Fig. 1), where the hole electrode is being able to inject holes in the channel layer. See, Exhibit B, Fig. 1 (page 2) and Fig. 8 (page 5); and
- a control electrode (n-doped Si in Fig. 1) positioned on the first side or on a second side of the channel. See, Exhibit B, Fig. 1 (page 2).

15. The scientific report also describes other features of the invention claimed in dependent claims: a dielectric layer which includes silicon oxide (SiO_2 layer in Fig. 1); electron electrode includes Au (legend of Fig. 1); the channel includes tetracene (Fig. 1 and Fig. 8); distance between the hole electrode and the electron electrode is 5 μm (Fig. 1 and page 2, line 5 below Fig. 1); "interdigitating fingers" structure of the electron and hole electrodes (Fig. 1 and page 2, lines 3-5 below Fig. 1); "P" and "R" values are the same (Fig. 1; lines 4-5); silicon wafer structure of the substrate (line 1 above Fig. 1).

16. Further, the scientific report reports data of experimental tests which were carried out with a device according to claim 1. See, in particular Figs. 2-6. The scientific report states that "a significant light output at relevant voltages confirms the injection of both electrons and holes" (page 2, lines 12-13 below Fig. 2 and Fig. 3). Also, Fig. 6 demonstrates that the observed emission originated from the tetracene and was not an artifact due to the utilized voltages (page 3, lines 4-13). Thus, these experiments prove that the invention was actually reduced to practice.

17. I submit that the scientific report which became the basis of the above-captioned application demonstrates that the invention was reduced to practice before February 3, 2003.

18. At the meeting, the Steering Committee decided to file a provisional application on the basis of this scientific report. The Steering Committee also determined the inventors on the basis of each inventor's contribution to the invention.

19. It was decided that the following inventors would be named: Michele Muccini; Paul Heremans; Johan Lieven Hendrik Reynaert; Raymond Ziessel; Aline Hepp; Roland Schmechel; Heinz von Seggern; and Holger Heil.

20. One of the participants at the meeting, Dr. Sigfried Karg, signed a copy of the report but was not named as an inventor because it was decided that he had not contributed to the invention.

21. The report was first sent to the Editor of Science journal with the specific request to keep it confidential and then, after the editor of Science declined to publish the manuscript, to the editor of Physical Review Letters journal with the specific request to keep it confidential. The report was received by the Physical Review Letters journal on April 4, 2003; the revised manuscript was received on June 20, 2003; and the report was published as a scientific article on October 10, 2003 (i.e., the article referred to as Hepp).

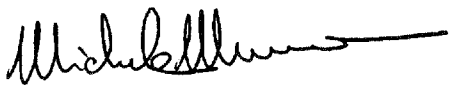
22. All but two co-authors of Hepp are named as co-inventors of the instant patent application.

23. I believe that Wieland Weise and Marcus Ahles, the two co-authors of Hepp who are not named as co-inventors of the instant patent application, were probably named as co-authors of Hepp based on a common academic practice whereby someone who lends substrates or instruments or conducts experiments under direction and supervision of the main author(s) is often named as a co-author.

24. The very fact that the scientific report was accepted for publication by Physical Review Letters is in itself evidence that the invention was reduced to practice because this scientific journal would not have accepted the report without experimental data providing support for the conclusions reached in the report.

25. Accordingly, I believe that the events described above amply demonstrate that the invention was conceived and reduced to practice with due diligence before February 3, 2003.

26. I hereby declare that all statements made herein of my own knowledge are true, and that all statements made on information and belief are believed to be true, and that these statements were made with the knowledge that willful false statements and the like so made are punishable by a fine or imprisonment, or both (18 U.S.C. Sec. 1001), and may jeopardize the validity of the application of ay patent issuing thereon.



Signed _____ Dated: __05 August 2010__

Michele Muccini

EXHIBIT A

(Declaration Under 37 C.F.R. §1.131 – Michele Muccini)

CURRICULUM VITAE ET STUDIORUM

Michele Muccini

CONTENT

1. General information

Place and date of birth: Pesaro (PU, Italy), 03/10/1967

Nationality: Italian

Home address: via P. Fabbri, 50, 40138 Bologna

Tel. 0541 733695

Legal status: married, 3 children

Degree: Doctor in Physics, 20/06/1991, at Università degli Studi di Bologna.

Languages: English: fluent; German: good knowledge

Current occupation:

Scientific Researcher III professional level – IV salary step
at CNR - Istituto per lo Studio dei Materiali Nanostrutturati
via P. Gobetti 101, 40129 Bologna
Tel. 051 6398521
Cellular phone 340 06 44 535
e-mail: M.Muccini@bo.ismn.cnr.it
web: www.ism.bo.cnr.it

2. Professional profile

My activity is inserted within the scientific area of Molecular Design and relates in particular to Molecular Electronics and Chemical-Physics. During the years I developed a broad range of multidisciplinary know-how including optical spectroscopy, vibrational spectroscopy, confocal fluorescence microscopy, electronic properties of organic materials, charge and energy transport in organic systems, growth of organic nanostructures by vacuum sublimation, fabrication and characterization of electronic and optoeletronic devices (LED, FET, LET) based on organics, development of novel instrumentation for advanced spectroscopic investigations.

I contributed to the understanding of the chemical-physical properties of molecular materials and investigated their potential for use in optoelectronic devices. In particular, I contributed to demonstrate a new class of organic optoeletronic devices, i.e. the Organic Light-Emitting Transistors (OLETs). I designed and fabricated scientific instruments, which are not commercially available, including an integrated system for the measurement of photoluminescence and electroluminescence quantum efficiency at controlled temperature. I designed and set-up a new Laboratory of *Confocal Nanophotonics* where optical nanoprobes allow correlating morphological and spectroscopic properties (also time resolved) of nanostructures with a spatial resolution of 100nm.

The activity required the capability to co-ordinate workgroups with 8-10 units.

Since January 2002 I am the head of the Research Unit "Nanosistemi Fotonici ed Optoelettronici" within the Research line "Nanostrutture Organiche per Elettronica, Fotonica e settori correlati" of the CNR-ISMN. The Research Unit is formed by 18 persons, 8 laboratories, and is involved in 4 European Projects, 2 of them managed as Co-ordinator, and one national project (FIRB). The Research Unit has been suggested as a *Commessa* by the Advisory Committee of the Department Molecular Design within the Project number 4 of the same Department.

I am well inserted within the international scientific community. I am involved in a number of international projects and I am Co-ordinator of two European Projects within the program *Future and Emerging Technologies* of IST. I belong to the Scientific Committee of the international Conference "Optical Probes of Conjugated Polymers". I regularly act as a scientific reviewer for top scientific international journals in the field of material science and chemical physics like i) Journal of the Americal Chemical Society; ii) Journal of Chemical Physics; iii) Chemical Physics Letters; iv) Advanced Materials; v) Advanced Functional Materials. I have been organizing international conferences and schools. I gave more than 40 talks at international conferences, 13 of which as invited. I have been editor of two books in the field of chemical physics of organic materials. I am inventor of 3 international patents and author of more than 80 scientific publications.

3. Research experience

I gained experience working in institutions of recognized scientific excellence (http://europa.eu.int/comm/research/era/mapping-excellence.html) also through national and international collaborations. In particular, I worked within the following projects:

1. CNR Projects, 1996-2000;
2. *Progetto Finalizzato* MSTAII;
3. European Projects ESPRIT–LEDFOS (1993-1996); HCM–SELMAT (1994-1996); TMR-SELOA (1996-2000); TMR–ENBAC (1996-2001); JOULE-THERMIE–EUROSCI (1996-1998); RTN–LAMINATE (2000-2004); RTD–MONALISA (2000-2003); IST–ILO (2001-2004); IST-PHOENIX (2002-2005);
4. Industrial Projects.

Positions:

1. Research Assignee at Istituto di Spettroscopia Molecolare, CNR Bologna, october 1992-september 1993.

2. Research Collaborator at Istituto di Spettroscopia Molecolare, CNR Bologna, october 1993-april 1994.

3. Reaserch Assitant at Fachbereich Physikalische Chemie (Department of Chemical Physics), Marburg University- Germany, may 1994 – june 1995.

4. Scientific Researcher III professional level at CNR - Istituto di Spettroscopia Molecolare di Bologna (Istituto per lo Studio dei Materiali Nanostrutturati from january 2002) from november 1994.

4. Scientific responsability of national and international projects

1. FIRB: Responsible of the Research Unit CNR-Bologna within the Project FIRB 2003 entitled *"Composti molecolari e materiali ibridi nanostrutturati con proprietà ottiche risonanti e non risonanti per dispositivi fotonici"*, coordinated by prof. Renato UGO. Within the same project I am coordinator of one of the four activities entitled "Studio delle potenzialità applicative in funzione di eventuali dimostratori".

2. EU V Framework Program: Responsible of the sub-project "*Nanoscale spectroscopic properties of ordered molecular architectures*" within the European Project IST-FET-PHOENIX, 2002-2005.

3. Bi-national Projects: National responsible for the bilateral project Italy-Portugal (CNR-ICCTI) "*Optoelectronic properties of organic conjugated thin films grown by vacuum sublimation*", 2001-2002.

4. EU V Framework Program: Responsible of the sub-project "*Electronic structure and energy transport in conjugated nanostructures and patterns*" within the European Project RTD - MONALISA, 2000-2003.

5. AGENZIA 2000: Responsible of the project CNR_AGENZIA 2000 "*Trasporto di Energia ed efficienza quantica di luminescenza in architetture sopramolecolari di oligomeri del tiofene*", 2001.

6. Progetto CNR: Responsible of the project at CNR - Istituto di Spettroscopia Molecolare in Bologna: "*Spettroscopia ottica lineare e non-lineare di materiali organici nanostrutturati*", 2000.

7. Progetto CNR: Responsible of the project at CNR - Istituto di Spettroscopia Molecolare in Bologna: "*Sistemi coniugati per l'elettronica e la fotonica*", 1997, 1998 e 1999.

8. Progetto CNR: Responsible of the project at CNR - Istituto di Spettroscopia Molecolare in Bologna: "*Caratterizzazione opto-elettronica ed energetica di composti organici per l'elettronica e la fotonica*", 1996.

5. Co-ordination and management of European Projects

V Framework Program of European Union

I am Co-ordinator of the European Project EU-IST-2001-33057 "*Injection Lasing in Organic Thin Films*" (ILO). The partnership is the following:

1. IBM Zurich Research Laboratory (CH)
2. IMEC - Interuniversity Microelectronics Centre, Leuven (B)
3. Darmstadt University of Technology (TUD), Institute of Materials Science, Darmstadt (D)
4. ECPM - Université Louis Pasteur - Ecole de Chimie, Polymère, Matériaux de Strasbourg, Strasburgo (F)

The total project cost is 3.547.631 Euro, of which 521.043 Euro is the funding of CNR-ISMN for the period 2001-2004.

Outcome of international scientific review

The project and its management have been evaluated a number of times by independent international scientific reviewers. In the following are reported some of the official evaluations:

1. "*This is an excellent and innovative project which should benefit both universities labs and companies in Europe*", from the Evaluation Summary Report prepared for projects selection.

2. "*The Project...shows promising results. Its results so far are highly innovative and at the forefront of the state-of-the-art. The selected methodology is sound. The project is managed efficiently*", from the Review Report after the I° year of activity.
3. "*The ambitious goal of developing an organic injection laser is at the forefront of research in the rapidly developing field of organic electronics. The management is dominated by the co-ordinator who is doing an excellent job*", from the Review Report after the II° year of activity.

4. "*The achievements of the project are a success and have a direct impact in the field of organic electronics. The work of the consortium is highly regarded in the international community. The work done in the framework of the project is clearly exceeding the state-of-the-art and further work in other groups may be initiated by the progress obtained within the ILO project. The results achieved in the frame of the ILO project can have high impact on organic optoelectronic applications. The partners are all aware of the latest developments in the field. The management is highly efficient, relying on a range of tools for information exchange like monthly teleconferences, or a confidential database where the results are made available to all consortium members as soon as they become available.*" from the Review Report after the III° year of activity.

VI Programma Quadro dell'Unione Europea

I am Co-ordinator of the European Project EU-IST-2005-015034-2 "*Organic electrically pumped LASer by engineering of heterostructures in field-effect devices*" (OLAS) currently under contract negotiation. The partnership is the following:

1. IBM Research GmbH (CH)
2. IMEC - Interuniversity Microelectronics Centre, Leuven (B)
3. Rheinisch-Westfaelische Technische Hochschule Aachen (RWTH), Aachen (D)
4. AMO GmbH (Gesellschaft fuer Angewandte Mikro – und Optoelektronik mbH), Aachen (D)

The total project cost is 3.932.000 Euro, of which 579.000 Euro is the funding of CNR-ISMN for the period 2005-2007.

Outcome of international scientific review

The project and the proposed management structure have been evaluated by independent international scientific reviewers. In the following are reported some of the official evaluations:

"The objectives are well defined and very challenging. The proposal contains a well-argued roadmap for the demonstration of electrically-pumped lasing. The idea of making photonic structures compatible with field-effect devices represents an innovative approach. The consortium is extremely well matched and committed to the project. The partners are complementary and the work plan demonstrates their commitment. The excellent records that some partners have in the field of organic electronics are additional strengths of the consortium. The coordinating partner possesses extensive experience in the management of such projects. Both the work plan and the management of knowledge are of high standard." from the Evaluation Summary Report prepared for projects selection.

6. Post-graduate teaching on the management of international research projects

I will hold a set of lectures on the topic "*Preparazione e Gestione di Progetti di Ricerca Europei*" within the University Master "*Compositi e nanotecnologie per l'aerospazio*" at Università la Sapienza in Rome, 23-25 maggio 2005. The lectures aim at providing the fundamental know-how in order to:

1. develop a method to focus a project idea;
2. create synergies among the partners of the consortium;
3. structure a workplan;
4. manage an international project both from the scientific and administrative point of view.

7. Responsability of a Research Unit at CNR-ISMN

Since January 2002 I am the head of the Research Unit "Nanosistemi Fotonici ed Optoelettronici" within the Research line "Nanostrutture Organiche per Elettronica, Fotonica e settori correlati" of the CNR-ISMN. The Research Unit has been suggested as a *Commessa* by the Advisory Committee of the Department Molecular Design within the Project number 4 of the same Department.

Currently the Research Unit is formed by the following persons:

1. Dr Michele Muccini (Ricercatore – Hed of Unit)
2. Dr Roberto Zamboni (I° Ricercatore)
3. Dr. Clara Santato (Ricercatore)
4. Dr Mauro Murgia (Tecnologo)
5. Dr Petr Nozar (Ricercatore a tempo determinato)
6. Dr Maria Antonietta Loi (Ricercatore a tempo determinato)

7. Dr Fabio Cicoira (Ricercatore a tempo determinato)
8. Tiziano Bonfiglioli (Tecnico)
9. Antonio Martiniello (Tecnico)
10. Pietro Fancello (tecnico a tempo determinato)
11. Franca Cesaro (Amministrativo)
12. Dr Arul Roy (Borsista Post-Dottorato ICTP)
13. Dr Raffaella Capelli (Assegnista di Ricerca)
14. Dr Stefano Toffanin (Assegnista di Ricerca)
15. Dr Francesco Todescato (Assegnista di Ricerca)
16. Dr Enrico Da Como (dottorando in Scienze Chimiche)
17. Dr Saverio Caria (dottorando in Scienze Chimiche)
18. Dr Cosimo Ancora (Borsista)

Currently the Research Unit has the following laboratories:

1. Laboratorio di crescita in UHV di Nanostrutture Organiche (O-MBD)
2. Laboratorio di Chimica-fisica delle superfici
3. Laboratorio di fabbricazione nanostrutture
4. Laboratorio di Spettroscopia Ottica
5. Laboratorio fabbricazione dispositivi optoelettronici
6. Laboratorio di Nanofotonica Confocale
7. Laboratorio di spettroscopia vibrazionale e Raman
8. Laboratorio di imaging ad onda evanescente

The Research Unit is involved in the following international projects:

1. EU-IST-2001-33057 "*Injection Lasing in Organic Thin Films*" (ILO), Funding for CNR-ISMN (2001-2004) 521.043 Euro
2. EU-IST-2001-38919 "*Photonic engineering of nonlinear-optical properties of hybrid nanomaterials for efficient ultrafast optical switching*" (PHOENIX), Funding for CNR-ISMN (2002-2005) 366.959 Euro
3. EUREKA-E!2541 "*Flexible Organic Illuminators for Automative Market*" (FOLIA), Funding for CNR-ISMN (2001-2004) 800.000 Euro
4. EU-IST-2005-015034-2 "*Organic electrically pumped LASer by engineering of heterostructures in field-effect devices*" (OLAS), Funding for CNR-ISMN (2005-2007) 579.000 Euro

As Head of the Research Unit I served as scientific responsible for PhD students, post docs, Research Assignees, fixed term appointed Scientific Researchers.

8. Duties

1. Responsible of the laboratory *"Optical Spectroscopy"* at CNR-ISMN Bologna from 1996.

2. Responsible of the laboratory *"Confocal Nanophotonics"* at CNR-ISMN Bologna from 2003
3. Responsible for CNR-ISMN-Bologna to maintain relations with the Software Consulting Company E-Level.

4. Member of the evaluation Committee for the selection of candidates for a Research Assignee on the topic "Spettroscopia ottica lineare e non-lineare di materiali organici nanostrutturati", at Istituto di Spettroscopia Molecolare, CNR Bologna, March 2000.

5. Member of the evaluation Committee for the selection of candidates for 2 positions of Research Assignees (Call n°126.133.AR.2 of 12 December 2001) at CNR-ISMN Bologna.

6. Member of the evaluation Committee for the selection of candidates for 1 position of Research Assignees (Call n°ADR/03/2003 of 04 March 2003) at CNR-ISMN Bologna.

7. Member of the evaluation Committee for the selection of candidates for 1 position of technical assistant with fixed term contract (Call n°ISMN-BO 01/03 of 12 May 2003) at CNR-ISMN Bologna.

8. Member of the evaluation Committee for the selection of candidates for 2 positions of scientific researchers with fixed term contract (Call n° ISMN-BO 02/03 of 30 May 2003) at CNR-ISMN Bologna.

9. External International Advisor for the PhD in Physics at University of Cambridge (UK), Year 2003

10. Member of the evaluation Committee for the selection of candidates for the access to the PhD in Chemical Sciences at Università di Bologna, year 2003/2004

11. Member of the evaluation Committee for the selection of candidates for 1 position of Research Assignee (Call n°ISMN-BO ADR/09/2005 of 12 January 2005) at CNR-ISMN Bologna.

12. Member of the evaluation Committee for the selection of candidates for 2 positions of Research Assignees (Call n°ISMN-BO ADR/10/2005 of 31 January 2005) at CNR-ISMN Bologna.

9. Technical-scientific responsability of international events

I have been co-chairman of the following international conferences:

1. 5th International Topical Conference on Optical Probes of Conjugated Polymers and Organic & Inorganic Nanostructures, Venezia, 9-14 February 2003.

2. Photonics Europe – SPIE International Conference, Simposium su "Organic Photonics and Optoelectronics", Strasbourg, 26-30 aprile 2004

I have been part of the organizing committee of the following schools and international conferences:

3. International School "SELOA (Synthetic Electroactive Organic Architectures) Summer School 2000" held on 20-25 May 2000 at CNR-Bologna.

4. International School "LAMINATE (Large-Area Molecular electronics Involving a Novel Approach to Training and Education) Summer School 2003" held on 25-30 May 2003 in Siena.

5. 8th European Conference on Molecular Electronics (ECME 8) to be held in Bologna from June 29 to July 2, 2005.

10. Membership of international scientific committee

I am part of the Scientific Committee of the International Conference "Optical Probes of Conjugated Polymers" devoted to organic semiconductors and molecular electronics.

11. Membership of Advisory Groups for European Commission policies

I am part of the group of International Experts acting as advisor for the European Commission to design future policies in order to realize the European Electronic Market.

12. Invited scientific talks

I gave more than 50 talks at national and international conferences and at national and international universities.

Invited talks at the following international conferences:

1. European Materials Research Society (E-MRS), spring Meeting June 1996, Symposium G, Strasbourg – Francia, titolo del seminario: "*Excitons and emission properties in organic materials*".

2. SPIE's International Symposium on Optical Science, Engineering and Instrumentation-Conference: Fullerenes and photonics IV, San Diego CA, 27 luglio-1 agosto 1997, titolo del seminario: "*Electronic structure of Fullerenes*".

3. SPIE's International Symposium on Optical Science, Engineering and Instrumentation-Conference: Optical Probes of Conjugated polymers III, San Diego CA, 27 luglio-1 agosto 1997. Titolo del seminario: "*Electronic excitations ordering in α-sexithiophene single crystal*".

4. SPIE's International Symposium on Optical Science, Engineering and Instrumentation - Conference: Third-order non-linear optical materials, San Diego CA, 19-24 luglio 1998, titolo del seminario: "*Optical properties of molecular materials*".

5. SPIE's International Symposium on Optical Science, Engineering and Instrumentation-Conference: Organic Light Emitting Materials and Devices II, San Diego CA, 19-24 luglio 1998, titolo del seminario: "*Effect of molecular aggregation on the optoelectronic properties of organic materials*".

6. European Materials Research Society (E-MRS), spring Meeting giugno 2000, Symposium I, Strasbourg – Francia, titolo del seminario: "*Basic properties of excitons in organic conjugated systems*"

7. European Conference on Organic Electronics and Related Phenomena 2001 – ECOER'01, titolo del seminario: *Fundamental Photphysics of Organic semiconductors* 18-21 novembre 2001 Potsdam - Germania.

8. Science and Technology of Organic Semiconductors, titolo del seminario: "*Blue Luminescence from fac Alq3*", 9-11 Dicembre 2002 Bad Honnef - Germania.

9. Organic Photonics Workshop - ECOER'01, titolo del seminario "*Injection Lasing in Organic Thin Films*", 22 Novembre 2003 Londra - Inghilterra.

10. Advances in Carbon Electronics – ACE II, titolo del seminario: "*Organic Light-Emitting Transistors*" 01 Ottobre 2003 Londra - Inghilterra.

11. Photonics Europe – SPIE International Conference, Conferenza Plenaria dal titolo: "*Organic Materials for Lasing Applications: Challenges and Perspectives*", 26-30 aprile 2004 Strasburgo - Francia

12. E-MRS 2004 Spring Meeting – Simposio E, titolo del seminario: "*Multifunctional Organic Devices*", 24-28 Maggio 2004, Strasburgo - Francia.

13. International Conference on Optical Probes of Conjugated Polymers and Biosystems – OP2005, Titolo del Seminario: "*Supramolecular organization in ultra-thin films of α-sexithiophene on silicon dioxide*" 4-8 Gennaio 2005, Bangalore – India.

Invited Talks at the following national and international Universities:

1. Università di Dortmund- Germania, titolo del seminario: "Two-photon absorption in C_{60} single crystal", 28 0ttobre 1994.

2. Università degli Studi di Milano, Dipartimento di Fisica, titolo del seminario: "Eccitoni in cristalli molecolari organici", 15 Marzo 1998.

3. Università degli Studi di Milano, Dipartimento di Fisica, titolo del seminario: "Mobilità degli eccitoni e trasferimento di energia in cristalli molecolari organici", 15 Marzo 1998

4. Università degli Studi di Milano, Dipartimento di Fisica, titolo del seminario: "Elettroluminescenza in materiali organici coniugati", 15 Marzo 1998

5. Università di Tübingen- Germania, Institut für Physikalische und Theoretische Chemie, titolo del seminario: "Optical properties of vacuum sublimed films and single crystals of α-Sexithienyl", 23 aprile 1998.

6. Politecnico di Milano, Dipartimento di Fisica, titolo del seminario: "*Film sottili di materiali molecolari per l'optoelettronica organica: correlazione tra crescita, ordine molecolare e proprietà ottiche*", 20 febbraio 2001.

7. Università dell'Insubria – Polo di Como, Dipartimento di Scienze CC.FF.MM, titolo del seminario: "*Film sottili di materiali molecolari per l'optoelettronica organica: correlazione tra crescita, ordine molecolare e proprietà ottiche*", 24 aprile 2001.

13. Teaching experience

1. Fixed term appointed professor at the faculty of Science of the University of Milano. Title of the course given: «Stati elettronici e proprietà ottiche di materiali molecolari funzionali», year 1997/1998.

2. Supervisor for the Diploma degree in Physics of Lucia Tinti at the Department of Physics of the University of Bologna. Title of the thesis: "Studio delle proprietà ottiche ed elettroniche di oligomeri del poli(peri-naftalene)", year 1997-1998.

3. Lecturer at Seminario Nazionale di Chimica Fisica 1999 "Materiali Funzionali" held on 20-25 giugno 1999 in Torino (Villa Gualino). Title of the lecture: "Proprietà ottiche e struttura elettronica di materiali organici coniugati per la fotonica e l'optoelettronica"

4. Lecturer at scuola internazionale "SELOA Summer School 2000" held on 20-25 may 2000 in Bologna. Title of the lecture: "Intermolecular interactions and energy transfer in nanostructured molecular materials".

5. Lecturer at scuola internazionale "LAMINATE Summer School 2003" held on 25-30 may 2003 in Siena. Title of the lectures: i) "Electronic structure of conjugated organic semiconductors - I"; ii) "Electronic structure of conjugated organic semiconductors - II".

6. Lecturer at Master Universitario di Primo livello "*Compositi e nanotecnologie per l'aerospazio*" in Rome (Università la Sapienza) that will be held on 23-25 maggio 2005. Title of the lecture: "*Preparazione e Gestione di Progetti di Ricerca Europei*".

14. Dissemination of scientific results

In close synergy with the press office of CNR, the most significant results have been disseminated via national mass media. In particular, the first demonstration of a new class of organic optoelectronic devices (OLETs) have been highlighted in a CNR press release dated 04/09/2003. Following this a number of articles have been devoted to the research activity of CNR on this topic.

1. La Stampa, 5 Settembre 2003
2. Il Resto del Carlino, 5 Settembre 2003
3. Il Sole24Ore, 6 Settembre 2003
4. Il Corriere della Sera, 5 Settembre 2003
5. La Repubblica, 5 Settembre 2003
6. Avvenire, 5 Settembre 2003
7. La Stampa Web, 5 Settembre 2003
8. Il Giornale di Brescia, 10 Settembre 2003
9. Libero, 11 Settembre 2003
10. Le Scienze, pag. 422 Ottobre 2003
11. Panorama, pag 207, 2/10/2003
12. ChiamamiCittà , pag 9, 19/11/2003

Membership of scientific Italian delegations at international meetings

I have been part of the Italian scientific delegation at the Italy-Israel bi-lateral meeting organized by the Ministry for International Affairs held on 16-18 Novembre 2003 in Tel Aviv, in order to promote know-how exchange between the two scientific communities and to provide stimulus for bilateral collaborations and joint initiatives within Europe.

15. Patents and exploitation activity

1. Brevetto USA n° US 6,552,791 B2 del 22 Aprile 2003; Brevetto Internazionale n° WO 01/48515 A2; Inventori: **M. Muccini**, and C. Taliani; Titolo dell'invenzione: "*Nondestructive apparatus and Method for detecting molecular orientation in thin films*"; Istituzione: Consiglio Nazionale delle Ricerche; Priorità Brevetto italiano: MI 99 A 002718, *Data di priorità:* 27.12.1999

2. Brevetto Internazionale n° WO 03/106422 A1, filing date 12 Giugno 2003; Inventori: **M. Muccini**, MA.Loi, N. Masciocchi, A. Sironi; Titolo dell'invenzione: "*Tris (8-ossichinolina) alluminio (III) (Alq3) con emissione nel blue*"; Istituzione: Consiglio Nazionale delle Ricerche. Priorità Brevetto italiano: MI 2002 A 001330, *Data di priorità:* 014.06.2002.

3. Brevetto USA Provisional Application n° 60/458,847 del 28.03.2003; Inventori: **M. Muccini**, H. Von Seggern, A. Hepp, R. Schmechel, P. Heremans, R. Ziessel; Titolo dell'invenzione: "*Organic electroluminescence generating devices*"; Estensione Internazionale PCT n° PCT/EP2004/003111; data di sottomissione: 24/03/2004.

The Intellectual Property protection activity is paralleled by the exploitation activity. National and international companies have expressed their interest for each of the three patents. As an example, the patent US 6,552,791 B2 and WO 01/48515 A2, has been licenced to a CNR Spin-off for direct exploitation.

16. Scientific Pubblications

Editing of volumes in the field of Chemical-Physics

1. Synthetis Metals Vol. 139 n°3 (2003) ISSN 0379-6779 "Special Issue- Proceedings of the Fifth International Topical Conference on Optical Probes of Conjugated Polymers and Organic & Inorganic Nanostructures" Edited by G. Lanzani, D. Comoretto, **M. Muccini**.

2. SPIE Vol. 5464 "Organic Optoelectronics and Photonics", edited by Paul Heremans, **Michele Muccini**, Hans Hofstraat, (SPIE, Bellingham, WA, 2004).

Scientific publications

1991

1. G.F. Missiroli, **M. Muccini**, G. Pozzi
   Olografia elettronica di campi elettrostatici generati da micropunte

XVIII CONGR. MICR. ELETT. Pg. 409 (1991).

1992

2. G. Matteucci, G.F. Missiroli, **M. Muccini**, G. Pozzi
Electron holography in the study of the electrostatic fields: the case of charged microtips
ULTRAMICROSCOPY 45 (1992) 77.

3. G. Matteucci, **M. Muccini**
Electron holographic simulations of the field of ferromagnetic tips
Atti di EUROPEAN CONFERENCE ON ELECTRON MICROSCOPY- EUREM, Vol. 1, Pg. 657 (1992).

1993

4. G. Matteucci, **M. Muccini**, U. Hartmann
Electron holography in the study of the leakage field of magnetic force microscope sensor tips
APPLIED PHYSICS LETTERS 62 (1993) 1839.

5. G. lanzani, R. Danieli, **M. Muccini**, C. Taliani
Picosecond time evolution of photoexcitations at 2.33 eV in α-Sexithienyl thin films
PHYSICAL REVIEW B 48 (1993) 15326.

6. G. Matteucci, and **M. Muccini**
On the mapping of leakage fields with double exposure electron holography: Influence of the second exposure
Atti di MULTINATIONAL CONGRESS ON ELECTRON MICROSCOPY, Pg. 351 (1993).

1994

7. Y.Achiba, K. Kikuchi, **M. Muccini**, G. Orlandi, G. Ruani, C. Taliani, R. Zamboni, F. Zerbetto
Preresonance Raman spectrum of C_{76}
JOURNAL OF PHYSICAL CHEMISTRY 98 (1994) 7933.

8. G. Matteucci, **M. Muccini**, U. Hartmann
Flux measurements on ferromagnetic microprobes by electron holography
PHYSICAL REVIEW **B** 50 (1994) 6823.

9. G. Ruani, C. Taliani, **M. Muccini**, K. Conder, E. Kaldis, H. Keller, D. Zech, K.A. Müller
Apex anharmonicity observed by Raman scattering in ^{18}O *substituted* $YBa_2Cu_3O_{6+x}$
PHYSICA C 226 (1994) 101.

10. G. Matteucci, **M. Muccini**, U. Hartmann
Stray-field investigations on sharp ferromagnetic tips by electron holography
JOURNAL OF MAGNETISM AND MAGNETIC MATERIALS 133 (1994) 422.

11. G. Matteucci, **M. Muccini**
On electron holographic mapping of electric and magnetic fields: recording and processing problems and field information reliability
ULTRAMICROSCOPY 53 (1994) 19.

12. C. Taliani, **M. Muccini**, R. Zamboni, F. Kajzar
Low energy excitons in solid C_{60}
MOL. CRYST. LIQ. CRYST. 256 (1994) 187.

13. C. Taliani, **M. Muccini**, R. Zamboni, F. Kajzar
Location of the lowest forbidden exciton in solid C_{60} by non linear spectroscopy
in "PROGRESS IN FULLERENE RESEARCH" Ed. H. Kuzmany, J. Fink, M. Mehring, S. Roth, World Scientific Pg. 407-411 (1994).

14. F. Kajzar, C. Taliani, **M. Muccini**, R. Zamboni, S. Rossini, R. Danieli
Third order nonlinear optical properties of Fullerenes
SPIE **2284** "FULLERENES AND PHOTONICS" (1994) Pg. 58-68.

15. R. Zamboni, **M. Muccini**, R. Danieli, C. Taliani, H. Mohn, W. Müller, H.U. ter Meer
Nonlinear spectroscopy of C_{60} single crystal
SPIE **2284** "FULLERENES AND PHOTONICS" (1994) Pg. 120-131.

16. G. Matteucci, **M. Muccini**
On the possibility to reveal charged dislocations by transmission electron holography
INTERNATIONAL CONFERENCE ON ELECTRON MICROSCOPY-ICEM, 13 Pg. 303 (1994).

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17. **M. Muccini**, R. Danieli, R. Zamboni, C. Taliani, H. Mohn, W. Müller, and H.U. ter Meer,
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18. **M. Muccini**, R.F. Mahrt, R. Hennig, U. Lemmer, H. Bässler, F. Biscarini, R. Zamboni, C. Taliani
Observation of interface excitons and energy transfer processes in an oligothiophene multilayer structure
CHEMICAL PHYSICS LETTERS 242 (1995) 207.

19. H. Schlaich, **M. Muccini**, J. Feldmann, H. Bässler, E.O. Göbel, R. Zamboni, C. Taliani, J. Erxmeyer, A. Weidinger
Absorption at the dipole-forbidden optical gap of crystalline C_{60}
CHEMICAL PHYSICS LETTERS 236 (1995) 135.

20. D. Cavalcoli, G. Matteucci, **M. Muccini**
Simulation of electron holographic contour maps of linear charged dislocations
ULTRAMICROSCOPY 57 (1995) 385.

21. G. Matteucci, **M. Muccini**, and D. Cavalcoli
Electron holography of magnetic and electric microfields
in "ELECTRON HOLOGRAPHY" ed. A. Tonomura et al., (1995) Pg. 159-168, Elsevier Science B.V.

22. **M. Muccini**, H. Schlaich, J. Feldmann, H. Bässler, E.O. Göbel, R. Zamboni, . Taliani, J. Erxmeyer, A. Weidinger
Observation of Stokes-shift in crystalline C_{60}
in "PHYSICS AND CHEMISTRY OF FULLERENES AND DERIVATIVES» Ed. H. Kuzmany, J. Fink, M. Mehring, S. Roth World Scientific Pg. 230-233 (1995).

23. D. Cavalcoli, G. Matteucci, **M. Muccini**
Can transmission holography reveal the electric potential of linear charged dislocations?
in «MICROSCOPY OF SEMICONDUCTING MATERIALS» IOP Publishing Ltd Pg. 91-94 (1995).

24. **M. Muccini**, H. Schlaich, J. Feldmann, H. Bässler, E.O. Göbel, R. Zamboni, C. Taliani, J. Erxmeyer, and A. Weidinger

Optical absorption and photoluminescence in crystalline C_{60}
SPIE **2530** «FULLERENES AND PHOTONICS II», Ed. by Zakya H. Kafafi,, Pg. 21-27 (1995).

25. **M. Muccini**, R.F. Mahrt, R. Hennig, U. Lemmer, H. Bässler, F. Biscarini, R. Zamboni, C. Taliani
Optic characterization of oligo-thiophene multilayers in «POLYMERS AND OTHER ADVANCED MATERIALS: EMERGING TECHNOLOGIES AND BUSINESS OPPORTUNITIES.» Edited by P.N. Prasad et al., Plenum press, New York, Pg. 297-302 (1995).

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26. **M. Muccini**
Optical properties of solid C_{60}
SYNTHETIC METALS 83 (1996) 213.

27. **M. Muccini**, H. Schlaich, J. Feldmann, H. Bässler, E.O. Göbel, R. Zamboni, C. Taliani, J. Erxmeyer, A. Weidinger
Investigation of the low energy optic excitations in crystalline C_{60}
SYNTHETIC METALS 77 (1996) 177.

28. Zamboni R, **Muccini M**, Abbate F, Kapousta O, Murgia M, Taliani C
Molecular beam deposition of fullerene based electroactive multilayer structures
ABST PAP AM CHEM SOCIETY 212: 286-PMSE Part 2 AUG 25 1996

29. **M. Muccini**, and C. Taliani,
Low energy electronic excitations in solid C_{60}
in "THE CHEMICAL PHYSICS OF FULLERENES 10 (AND 5) YEARS LATER", Ed. W. Andreoni, Kluwer Academic Publishers Pg. 99-116 (1996).

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Frenkel and charge transfer excitons in solid C_{60}
in "FULLERENES AND FULLERENE NANOSTRUCTURES" Ed. H. Kuzmany, J. Fink, M. Mehring, S. Roth, World Scientific (1996) Pg. 559-563.

31. R. Zamboni, **M. Muccini**, O. Kapousta, M. Murgia, F. Abbate, E. Lunedei, C. Taliani, F. Kajzar
Optical properties of Fullerene-based hetero-multilayers grown by Molecular Beam Deposition
SPIE **2854** «FULLERENES AND PHOTONICS III», Ed. by Zakya H. Kafafi, (1996) Pg. 182-189.

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32. R.N. Marks, F. Biscarini, T. Virgili, **M. Muccini**, R. Zamboni, and C. Taliani
The growth and characterization of α-sexithienyl based ligth-emitting diodes
PHIL. TRANS. ROYAL SOC. LOND. A 355, 763 (1997)

33. **M. Muccini**, E. Lunedei, C. Taliani, F. Garnier, and H. Baessler
Ordering of low energy electronic excitations in α-sexithiophene single crystal
SYNTHETIC METALS 84 (1997) 863.

34. **M. Muccini**, E. Lunedei, C. Taliani, F. Garnier, and H. Baessler
Defect state emission in α-sexithiophene single crystal
SYNTHETIC METALS 84 (1997) 599.

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35. **M. Muccini**, E. Lunedei, A. Bree, G. Horowitz, F. Garnier, and C. Taliani
Polarised Fluorescence in α-Sexithienyl Single Crystal at 4.2 K
JOURNAL OF CHEMICAL PHYSICS 108, 7327 (1998).

36. **M. Muccini**, E. Lunedei, C. Taliani, D. Beljonne, J. Cornil, and J.L. Brédas
Interchain interaction in a prototypical conjugated oligomer from polarized absorption at 4.2K: α- sexithienyl single crystal
JOURNAL OF CHEMICAL PHYSICS 109, (1998) 10513.

37. R.N. Marks, **M. Muccini**, E. Lunedei, R.H. Michel, M. Murgia, R. Zamboni, C. Taliani, G. Horowitz, F. Garnier, M. Hopmeier, M. Oestreich, R.F. Mahrt
Disorder influenced optical properties of α-sexithiophene single crystals and thin evaporated films
CHEMICAL PHYSICS 227 (1998) 49.

38. M. Hopmeier, R.N. Marks, R. Mitchel, **M. Muccini**, M. Murgia, R. Zamboni, C. Taliani, G. Horowitz, F. Garnier, M. Oestreich, and R. F. Mahrt
Excitation dynamics in α-sexithiophene single crystals and UHV-grown films"
JOURNAL OF LUMINESCENCE 76, (1998) 416.

39. **M. Muccini**
Low energy electronic and optical properties of α-sexithiophene single crystal"
MATERIALS SCIENCE & ENGINEERING C5, 173 (1998)

40. E. Lunedei, R.N. Marks, **M. Muccini**, M. Murgia, R. Zamboni, C. Taliani, R.F. Mahrt
Organic heteromultilayers: electronic structure of α-sexithienyl/C_{60} thin films grown in ultra-high vacuum
PURE AND APPLIED OPTICS 7 (1998) 151.

1999

41. G. Cerullo, G. Lanzani, **M. Muccini**, C. Taliani, and S. De Silvestri
"Real Time Vibronic Coupling Dynamics in a Prototypical Conjugated Oligomer"
PHYSICAL REVIEW LETTERS 83, 231 (1999)

42. **M. Muccini**, E. Lunedei, and C. Taliani
"Polarized Absorption and Davydov Splitting in α-sexithienyl Single Crystal at 4.2K"
SYNTHETIC METALS 101, 573 (1999)

43. G. Wegmann, R.F. Mahrt, H. Baessler, H. Giessen, M. Murgia, O. Kapousta, **M. Muccini**, C. Taliani, and R. Zamboni
"Femtosecond Transient Absorption Spectroscopy in α-sexithienyl thin films"
SYNTHETIC METALS 101, 555 (1999)

44. G. Ruani, V. Dediu, M. Liess, E. Lunedei, R. Michel, **M. Muccini**, M. Murgia, C. Taliani, and R. Zamboni
"Photoinduced charge transfer in complex architectured films of C_{60} and donor-like molecules"
SYNTHETIC METALS 103, 2392 (1999)

45. E. Lunedei, P. Moretti, M. Murgia, **M. Muccini**, F. Biscarini, and C. Taliani
"Morphology dependent fluorescence in α-sexithienyl thin films at 4.2 K"
SYNTHETIC METALS 101, 592 (1999)

46. G. Cerullo, G. Lanzani, **M. Muccini**, C. Taliani, and S. De Silvestri
"Coherent vibrational dynamics in sexithiophene films"

SYNTHETIC METALS 101, 614 (1999)

47. G. Cerullo, G. Lanzani, **M. Muccini**, C. Taliani, and S. De Silvestri
"Collective vibrational coherence in sexithiophenes films"
OPTICAL MATERIALS 12, 383 (1999)

48. L. Tinti, **M. Muccini**, R. Zamboni, R.F. Mahrt, K. Muellen, and C. Taliani
"The effect of intramolecular interaction on the electronic properties of quaterylene"
SYNTHETIC METALS 102, 1589 (1999)

49. R. Zamboni, **M. Muccini**, W. Gebauer, F. Biscarini, M. Murgia, G. Ruani, D. A. Leigh, A. Murphy, and D. Tetard
"Raman and Far Infrared Characterization of the Simplest Benzylic Amide [2] Catenane"
SYNTHETIC METALS 102, 1556 (1999)

50. C. Taliani, F. Biscarini and **M. Muccini**
"Intermolecular Interactions and Energy Transfer in Solid α-sexithienyl "
in " CONJUGATED OLIGOMERS, POLYMERS AND DENDRIMERS: FROM POLYACETYLENE TO DNA" Ed. By J.-L.Brédas, De Boeck Université, Brussels, Pg. 163-204 (1999).

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"Electronic structure and energy transfer in Solid α-sexithienyl "
in "SEMICONDUCTING POLYMERS –CHEMISTRY, PHYSICS AND ENGINEERING" Ed. by G. Hadziioannou and P.F. van Hutten, WILEY-VCH, Weinheim, Pg. 149-188 (1999).

2000

52. M. Brinkmann, G. Gadret, **M. Muccini**, C. Taliani, N. Masciocchi, and A. Sironi
"Correlation between molecular packing and optical properties in different crystalline polymorphs and amorphous thin films of mer-tris-(8-hydroxyquinoline)-alluminum (III)"
JOURNAL OF THE AMERICAN CHEMICAL SOCIETY, 122, 5147 (2000)

53. A. Degli Esposti, M. Fanti, C. Taliani, **M. Muccini**, G. Ruani
The Polarized Infrared and Raman Spectra of α-T_6 Single Crystal: an Experimental and Theoretical Study"
JOURNAL OF CHEMICAL PHYSICS, 112, 5957 (2000)

54. **M. Muccini**, M. Schneider, C. Taliani, M. Sokolowski, E. Umbach, D. Beljonne, J. Cornil, and J.L. Brédas
"The effect of wave-function delocalization on the exciton splitting in organic conjugated materials"
PHYSICAL REVIEW B, 62 (2000) 6296.

55. P. Mei, M. Murgia, C. Taliani, E. Lunedei, and **M. Muccini**
Luminescence Quantum Yield of Molecular Aggregates and Excitons in α-Sexithienyl Thin Films at Variable Temperature"
JOURNAL OF APPLIED PHYSICS, 88 (2000) 5158

56. **M. Muccini**, M. Murgia, C. Taliani, A. Degli Esposti, and R. Zamboni
"Optical properties and photoluminescence quantum yield of organic molecular materials"
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"Optical spectroscopy of unsolvated and solvated crystalline Alq_3"
SYNTHETIC METALS, 122 (2001) 31.

59. **M. Muccini**, M. Schneider, and C. Taliani
"Chainlength dependence of interchain splitting in electroluminescent organic conjugated materials"
SYNTHETIC METALS, 116 (2001) 301.

60. **M. Muccini**, M. Murgia, and C. Taliani
"Temperature dependent optical emission efficiency in vacuum sublimed α-sexithienyl thin films"
SYNTHETIC METALS, 121 (2001) 1347.

61. M. Brinkmann, G. Gadret, C. Taliani, N. Masciocchi, A. Sironi, and **M. Muccini**
"Interplay between optical properties and molecular packing in novel isolated crystalline phases of tris-(8-hydroxyquinoline) Aluminium (III)"
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62. A.degli Esposti, **M. Muccini**, G. Ruani
"Modelling of vibrational Davydov splitting in α-sexithienyl"
SYNTHETIC METALS, 119 (2001) 237.

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Morphology and trap luminescence in thin oligothiophene films on HOPG
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Organic light emitting diodes with spin polarized electrodes
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SYNTHETIC METALS 139 (2003) 551

68. Loi MA, Da Como E, Zamboni R, **Muccini M**
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SYNTHETIC METALS 139 (2003) 687

69. Capelli R, Taliani C, **Muccini M**
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Optical coupling of flexible microstructured organic light sources for automotive applications
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Blue Luminescence of Facial Tris(quinolin-8-olato) Aluminium(III) in Solution, Crystals and Thin films
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Ambipolar Light-Emitting Organic Field-Effect Transistor
APPLIED PHYSICS LETTERS 85 (2004) 1613

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Tetracene based Organic Light-Emitting Transistors: optoelectronic properties and electron injection mechanism
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Light-emitting Ambipolar Organic Heterostructure Field-Effect Transistor
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Photonic engineering of nonlinear-optical properties of hybrid materials for efficient ultrafast optical switching (PHOENIX)
SPIE **5464** «Organic Electronics and Photonics», Ed. by P. Heremans, **M. Muccini**, H. Hofstraat (2004) Pg. 39.

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NATURE MATERIALS 4 (2005) 81

79. F. Cicoira, C. Santato, F.Dinelli, M.Murgia, M.A. Loi, F.Biscarini, R. Zamboni, P.Heremans,

and **M. Muccini**
Correlation between morphology and filed-effect transistor mobility in tetracene thin films
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80. C. Santato, I. Manunza, A. Bonfiglio, F. Cicoira, P. Cosseddu, R. Zamboni, **M. Muccini**
Tetracene light-emitting transistors on flexible plastic substrates
APPLIED PHYSICS LETTERS, 86 (2005) 141106

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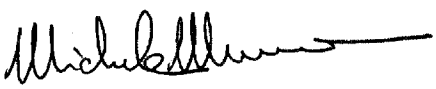
Bologna, 28 Aprile 2005



Dr. Michele Muccini

EXHIBIT B

(Declaration Under 37 C.F.R. §1.131 – Michele Muccini)

Light-Emitting Field-Effect Transistor Based on Polycrystalline Tetracene

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Abstract

In this paper the operation of the first organic light-emitting field-effect transistor based on a polycrystalline tetracene layer vapour-deposited on a silicon/silicon dioxide substrate is reported. Source-drain electrodes are arranged as interdigitated fingers in bottom contact configuration with a channel length of 5 µm and a channel width of 20 cm. It is demonstrated that the injection of holes and electrons from gold source and drain electrodes, respectively, lead to the characteristic tetracene emission, which can be modulated by the gate voltage. The electrical output characteristics, the electrical transfer characteristics and the corresponding optical emission properties of the field effect transistor are reported proving the possibility of modulation of emitted light from an organic transistor by gate-voltage.

Introduction

Since its discovery [1] organic field effect transistors (OFETs) have been investigated extensively as demonstrated in recent review articles [2, 3]. During the last ten years interest shifted from material related topics to morphology optimisation, both for vacuum deposited small molecules and polymeric semiconductors. Also the influence of substrate surface treatment [4] was found to be of major importance for the obtainable morphology of the semiconducting layer, which on the other hand determines the charge carrier mobility, trap distribution, etc. [5]. And it has been demonstrated that such OFETs exhibit the capability to drive an organic light-emitting diode (OLED) [6, 7].

Usually organic field effect transistors are operating in a unipolar accumulation mode. In principle, however, a bipolar operation should be possible. The bipolar operation mode includes carrier recombination and consequently light emission. Such a light emitting field-effect transistor (LEFET) is not only the smallest possible combination of light source and switch, it further allows an electrical control over the recombination zone. This is important for applications in the optical information technique. 2000 a light-emitting transistor based on a α-6T single crystal was presented [8]. This device concept was consequently extended to an organic injection laser based on a tetracene single crystal [9]. But these publications were withdrawn recently [10] due to proven misconduct of experimental data [11]. Furthermore, no other research group could confirm the light emission from an OFET. However, in principle an OFET should be able to work in a bipolar mode, which includes recombination of carriers and consequently light emission.

In the present study the observation of light emission from an organic field effect transistor based on a vacuum-deposited tetracene layer is shown. It will be demonstrated that this LEFET exhibits electrical characteristics similar to an unipolar OFET and the emitted light intensity can be modulated by gate and drain voltage. An attempt will be made to explain the unexpected electron injection in such a device using gold electrodes as source and drain contacts.

The content of this paper has been disclosed under confidentiality to Dr Michele Muccini and Dr Sigfried Karg on January the 28th 2003 by electronic mail and to Dr Paul Herrmann and to Dr Raymond Zenzel at the Steering Committee Meeting held in Bolzano on February the 3rd 2003.

Experimental

The here shown LEFETs were fabricated upon heavily doped n-type silicon substrates (3-5

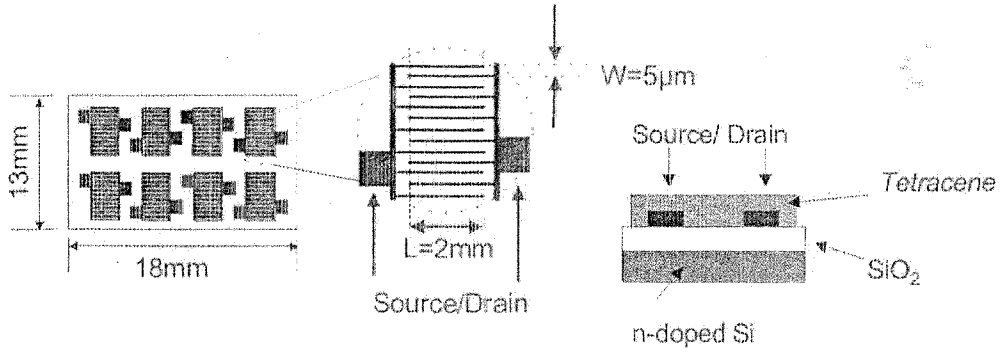

Fig. 1 Electrode configuration of the utilized LEFET: a) wafer layout with 8 LEFET structures, b) part of the layout structure of a single LEFET, c) cross section of two neighboring Au electrodes.

Ωcm) covered by a high quality thermal oxide of about 285 nm thickness establishing the gate electrode and gate oxide, respectively. A 50 nm Au layer is deposited on the complete oxide surface utilising a thin Cr adhesive layer. The Au source and drain electrodes are photolithographically structured. They are configured as interdigitating fingers with a channel length of 5 µm and a channel width of 20 cm. The layout of the electrodes is displayed in Fig.1. The so prepared base structures were treated by the silane coupling agent n-Octadecyldimethylchlorosilane (OMS) to improve tetracene film formation onto the substrate surface. With no further contact to ambient air the substrates were then transported to an evaporation chamber with a base pressure of $1 \cdot 10^{-6}$ mbar. Subsequently tetracene (Chemos GmbH) was thermally evaporated with a deposition rate of 5Å/s onto the surface of the OFET structure.

The output and transfer characteristics of the LEFET were measured with an HP parameter-analyser (HP 4155A) and the integral emission intensity was recorded by means of a Si-photodiode mounted about 2 millimetres above the emitting LEFET surface. The diode photocurrents were also fed into the parameter analyser. The emission spectrum was recorded with an optical simultaneous multi-channel analyser (OSMA).

Results and Discussion

A typical output characteristic of a LEFET is displayed in Fig. 2.

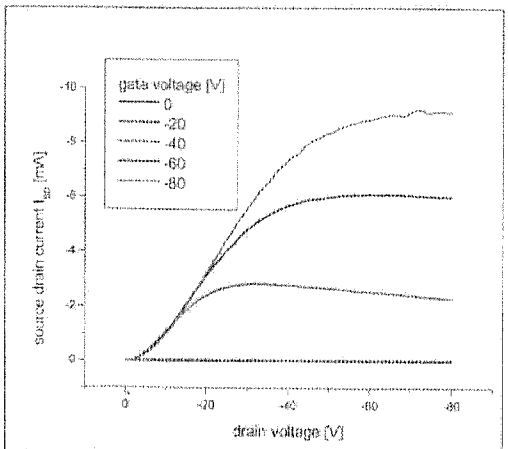

Fig. 2 Output characteristics of an LEFET for different gate voltages.

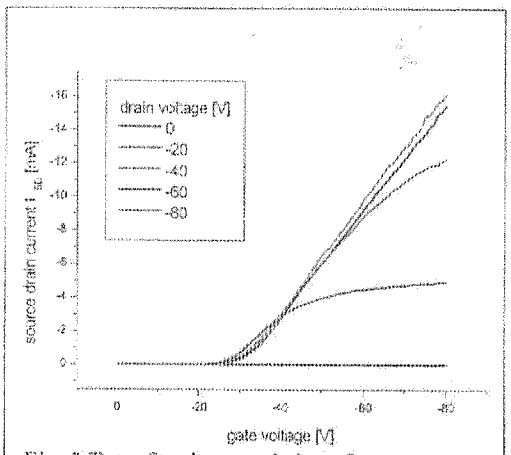

Fig. 3 Transfer characteristics of a tetracene OFET for different source-drain voltages

It exhibits the characteristics of an unipolar field-effect transistor with good saturation behaviour. The transistor operates in hole accumulation mode. The electrical transfer characteristics are displayed in Fig. 3. Field effect hole mobilities and threshold voltages were derived from a fit to the linear regime in the $\sqrt{I_D}(V_G)$-plot of the transfer characteristics [2] and are in the range of $\mu = 5 \cdot 10^{-2}$ cm^2/(Vs) or $V_{th} = -24$ V, respectively. The threshold voltage of –24 V indicates a high concentration of trap states. On/off ratios were determined from the transfer characteristics, as well, and were in the range of of $1 \cdot 10^6$. The S-shaped curvature at small voltages in the output characteristic indicates the presence of an injection barrier even for holes from the Au electrode into the tetracene HOMO levels.

The electrical characteristics show no indication for an ambipolar transport. Furthermore, it was not possible to operate the transistor in a pure n-type inversion mode. Obviously, the electron mobility is low and the electron injection is weak. However, a significant light output at relevant voltages confirms the injection of both electrons and holes. The optical output of the same LEFET is displayed in Fig. 4.

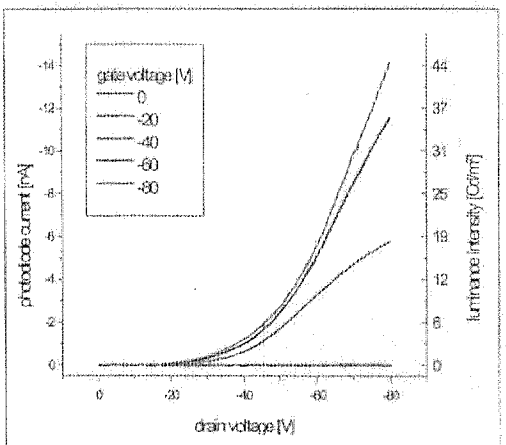

Fig. 4 Optical output characteristics of the tetracene LEFET as recorded by a photodiode for different source-gate voltages

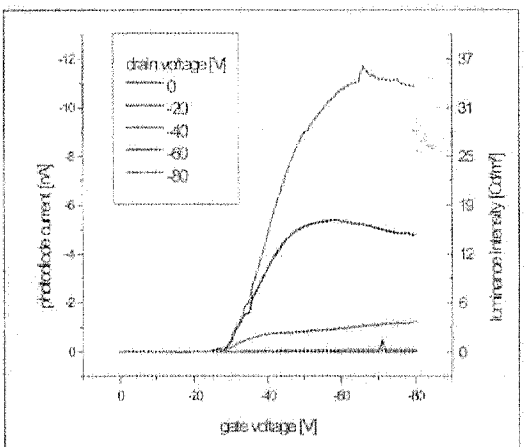

Fig. 5 Optical transfer characteristics of the tetracene LEFET as recorded by a photodiode for different source-drain voltages

It was recorded parallel to the electrical characterization. It is beyond any doubt that the light output of the LEFET can be controlled by the gate voltage, which corresponds to the control of the source-drain current in a normal field-effect transistor.

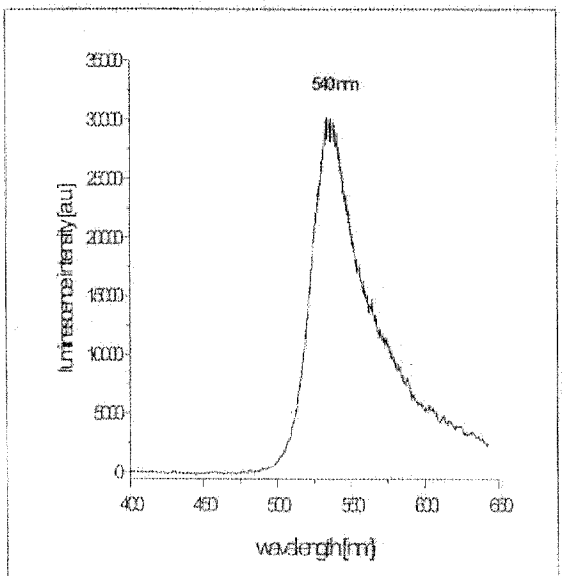

Fig. 6 Emission spectrum of the LEFET with V_G^{∞} - 80V and V_{SD}^{∞} - 80V

In order to prove, that the observed emission originates from the tetracene and was not an artifact due to the utilized high voltages, the emission spectrum has been recorded in the spectral range between 400 and 650 nm. The spectrum shows the expected transition at 540 nm, which is well known for the green color of tetracene [12] and is displayed in Fig. 6. The green emission can also be seen from the operating device in Fig. 7 where one of the eight transistors is connected. Displayed is a digital image of the actual device and one faintly recognizes 4 of the 8 electrode configurations as displayed in Fig. 1. The luminance of the emissive region was determined to 45 Cd/m². However, this value only gives an estimate, as the light emitting area of the transistor was not fully accessible for luminance measurements.

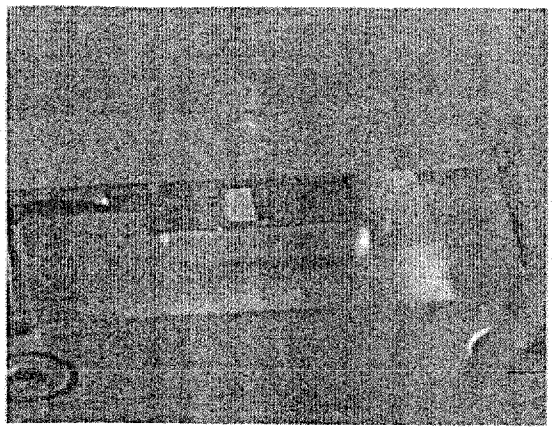

Fig. 7 Actual image of the first polycrystalline light-emitting OFET within an electrode layout as displayed in Fig. 1. The size of the LEFET is 2x8mm^2 whereby the emitting area is at most 1mm^2 due to the electrode areas of the interdigitating electrodes

Concerning the mechanism in detail, some questions remain:

1. The injection problem: As mentioned above, the transistor operates in a hole accumulation mode, which is expected due to the relative small injection barrier for holes from Au electrodes to the HOMO levels of tetracene. Reported values are 5.1 eV for the workfunction of Au and 5.4 eV for tetracene [13] result in a barrier height of 0.3 eV, which is easy to overcome at room temperature. Taking into account the known LUMO position of tetracene of 2.4 eV [13] this suggests that electrons have to surmount a barrier of approximately 2.7 eV, which seems to be impossible by thermal means alone. The question that arises at this point is, what makes such an electron injection possible. At present we are not able to answer this question, however, a few suggestions will be given. First of all we are using tetracene as bought, without any further cleaning or sublimation. Therefore, the material may contain impurities, which either act as energetically low lying traps or as source for free ions in the semiconductor. Both circumstances would lower the effective potential barrier either by providing an energetic staircase for the electrons into the tetracene [14] or by doping the tetracene like in an electrochemical cell [15]. Another possibility would be the generation of a large number of grain boundaries, which, as in the case of impurities, would generate energetically intermittent states again acting as a kind of staircase. Nevertheless, the high negative threshold voltage indicates a high concentration of hole traps. According to the basic thin film transistor theory [2] the concentration of trap states can be estimated from the threshold voltage to an order of magnitude of 10^{17}cm^{-3}.

2. The onset of the light emission at $U_{SD} \approx -20$ V is independent of the gate voltage: Only the light intensity is controlled by the gate voltage. Following thin film transistor theory one only would expect a bipolar operation of the transistor, if the drain voltage exceeds the gate voltage. But, as presented in Fig. 4, even at a gate voltage of –80 V, the light output starts at a drain voltage of –20 V. In principle, an accumulation of electrons in the channel at these voltages is not possible. However, the effective situation in the transistor might be more complex than in the simple picture. hence, the source and drain electrodes could be underetched, as schematically presented in figure 8. This is a well-known problem for the electrochemical etching process, which has been used here for patterning. A shadow effect during the deposition of tetracene causes an imperfect contact of the tetracene layer to the source and drain electrodes close to the insulator interface. During operation the channel is filled with holes at the organic/insulator interface (hole accumulation mode). However, due to

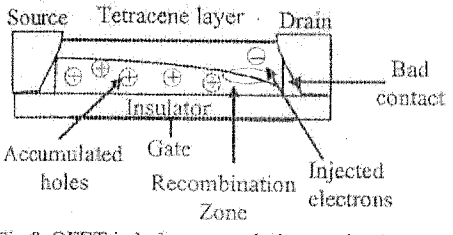

Fig 8. OFET in hole accumulation mode, due to an imperfect contact on the drain electrode electrons can be injected far away from the gate insulator.

drain electrode. Those parts of the tetracene layer that are directly connected to the electrodes are far away from the gate insulator. There the field of the gate electrode is mainly screened by the positive charge of the holes on the insulator interface. Now, electrons can be injected from the drain electrode.

Despite the fact that the present LEFET is still in its preliminary state and not all mechanisms are understood in detail, the practical implications of such a device can be very large. The LEFET, if properly designed, could replace the presently used combination of thin-film transistors (TFTs) with imaging devices such as liquid crystal displays (LCDs) or OLEDs. The advantage of the present design compared to any single crystal approach is the ability to vapour deposit the organic semiconductor which can be performed on any kind of substrate, even on a plastic surface and there is a good chance that LEFETs can be produced also with other light emitting materials inclusive polymers.

Acknowledgements

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